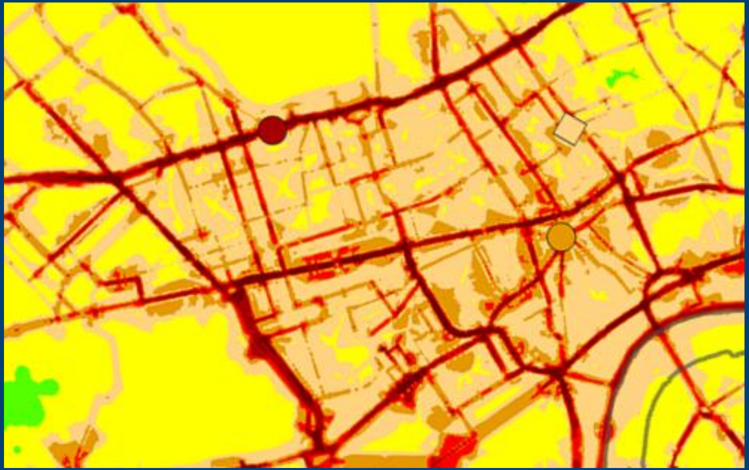
Best practice air quality modelling using ADMS



Dr Jenny Stocker

Routes to Clean Air 2018
October 2018

Birmingham

CERC
Cambridge Environmental Research Consultants
Environmental Software and Services

Outline

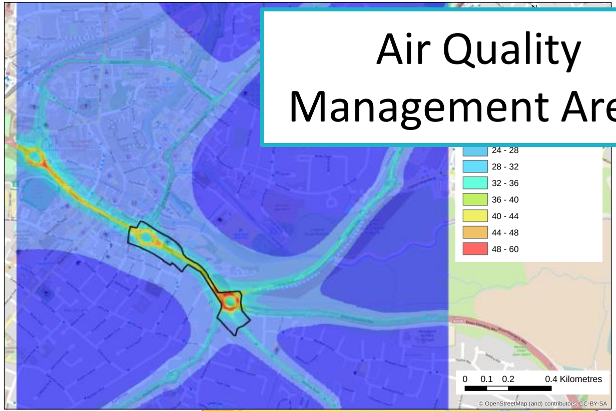
- Introduction to ADMS
- What governs air quality?
- ADMS model configuration tips
- Air quality modelling tips
- Uncertainty of model results
- Software support
- References

Introduction to ADMS (1 of 2)

- **ADMS** – **A**tmospheric **D**ispersion **M**odelling **S**ystem
- Desktop software tool for numerically modelling the impacts of air pollutant emissions (air pollutant concentrations, dry and wet deposition fluxes, odour…)
- A ‘new generation’ quasi-Gaussian plume air dispersion model, i.e. atmospheric boundary layer properties are characterised by two parameters: boundary layer depth and Monin-Obukhov length
- Scales:
  - Spatial – ‘street scale’ (few metres) to ~ 50 km or larger (when coupled to a regional model)
  - Temporal – hourly calculations used to evaluate Air Quality Standards, also fluctuations for calculating sub-hourly concentration distributions
- Various versions of the model are specifically applicable to different applications, e.g. industrial (ADMS 5), traffic and urban areas (ADMS-Urban and ADMS-Roads), airports (ADMS-Airport), dense gases (ADMS-Puff, GASTAR)

Introduction to ADMS (2 of 2)

- **ADMS** – **A**tmospheric **D**ispersion **M**odelling **S**ystem
- Widely used in the UK, Europe and worldwide by companies, regulatory bodies, local and national government, and research organisations for…



Air Quality Management Areas

Planning applications

Permitting applications

Clean Air Zones

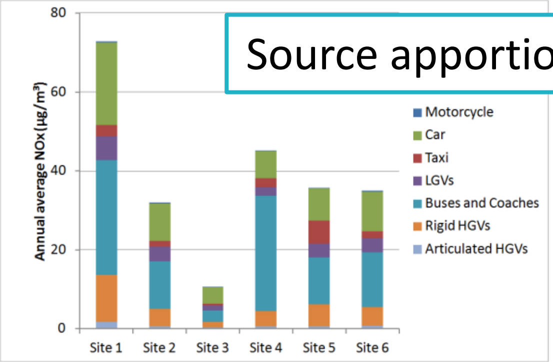
Stack height determination

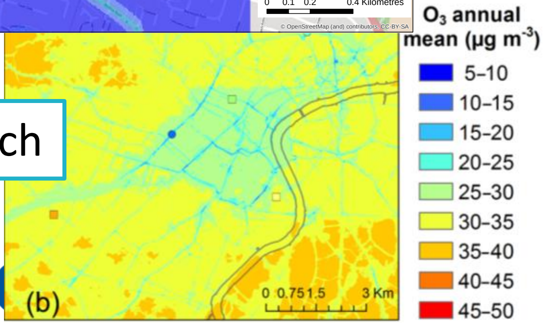
Inputs to health studies

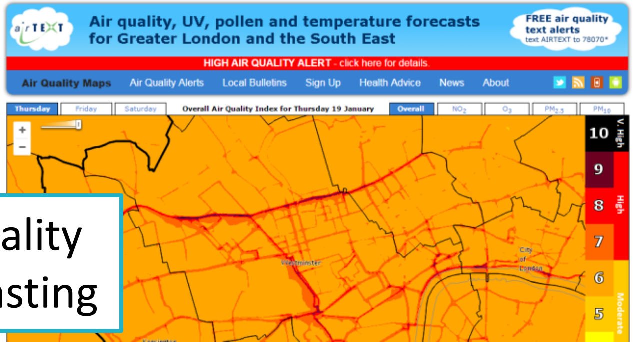
Air quality forecasting

Research

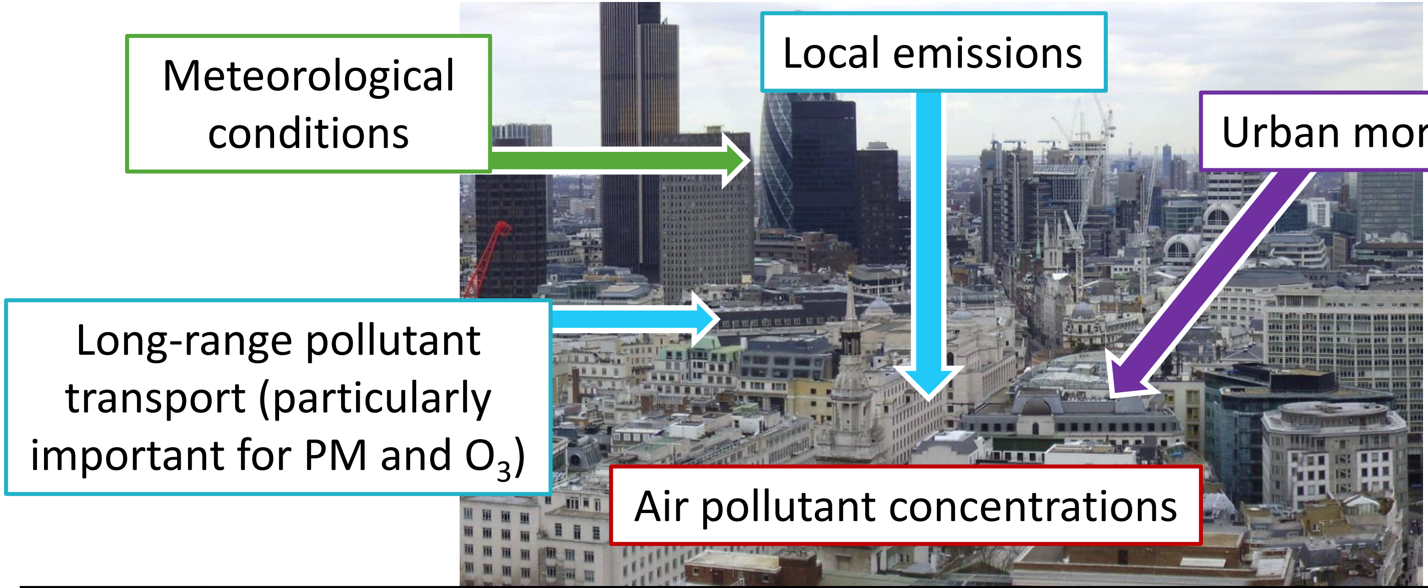
Source apportionment







What governs air quality?



Local emissions and **long-range pollutant transport** must be accounted for in ADMS

Method	Description	Issues
Best practice	Include all urban emissions explicitly and use upwind rural measurements to account for long-range transport	Too time consuming for the majority of planning applications, EIAs
Usual approach	Use 'urban background' to represent long-range transport and some urban sources, and explicitly represent local sources	What does the 'urban background' represent? Be careful not to double-count emissions. Difficult to account for chemistry precisely.

ADMS model configuration tips (1 of 9)

Meteorological (met) data

- For most modelling studies, met data are not from the study site
- Met data often from an airport which, compared to study site, is:
    - more open (lower roughness length)
    - more rural (meteorological conditions more stable)
- ADMS can account for difference in conditions between met station and study site (5 parameters available; roughness; and minimum Monin-Obukhov length most important)

Many users do not use this model feature!

- This model feature is very important because the difference in roughness length between the study site and met station leads to difference in wind speed, which strongly influences dispersion

Open (low roughness)

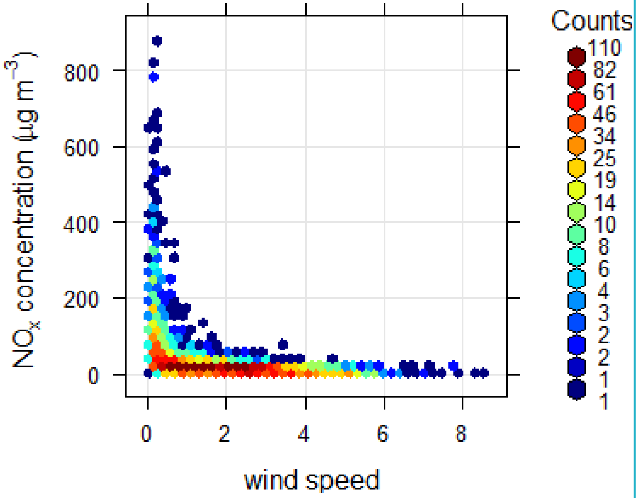
Built up (high roughness)

ADMS model configuration tips (2 of 9)

Meteorological (met) data

- **Why is the wind speed so important?**
- Because concentrations have an approximately inverse dependence on wind speed (plus dependence on other factors)

Hourly NO_x concentrations at Thurrock Stanford-le-Hope (TK3) in 2014



- Modelling using higher wind speeds from an airport will lead to lower (incorrect) concentration predictions in urban areas

Open (low roughness)

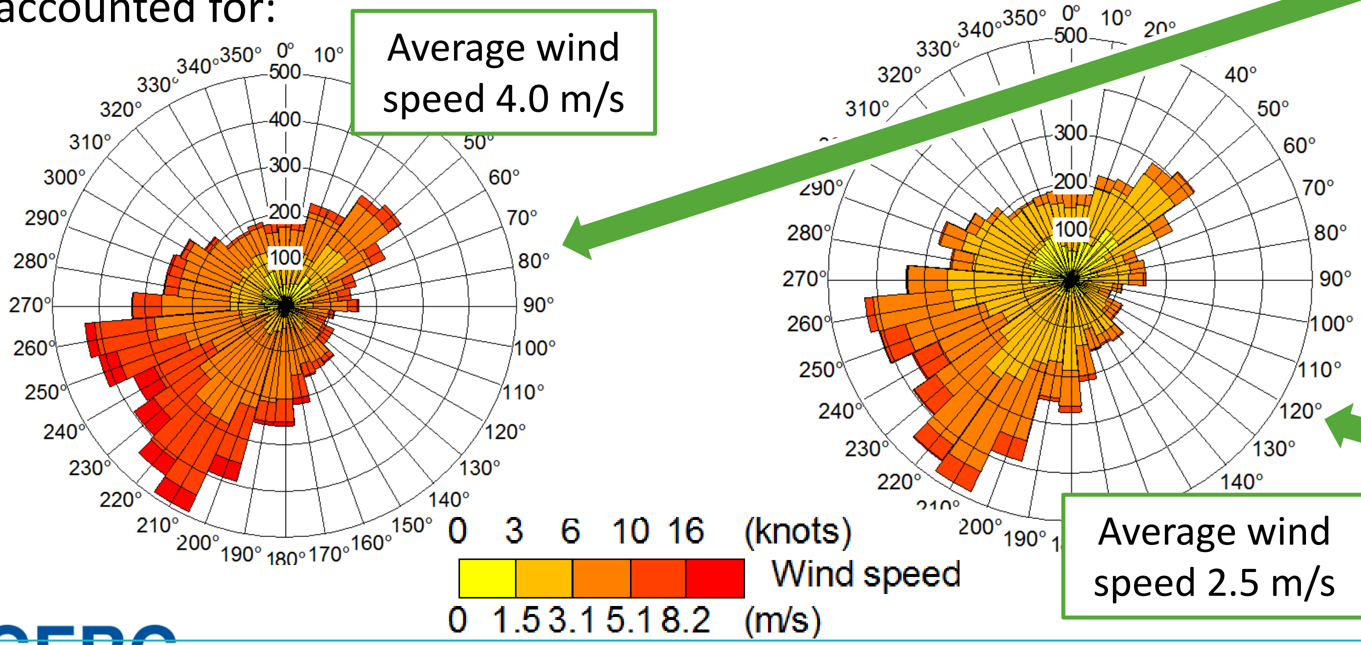
Built up (high roughness)

CERC

ADMS model configuration tips (3 of 9)

Meteorological (met) data

- **Best practice:** include wind roses for both sites in your report, to show how the differences in meteorological conditions have been accounted for:



Open (low roughness)

Built up (high roughness)

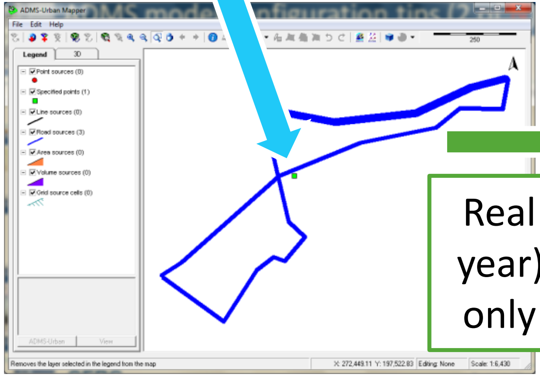
CERC

ADMS model configuration tips (4 of 9)

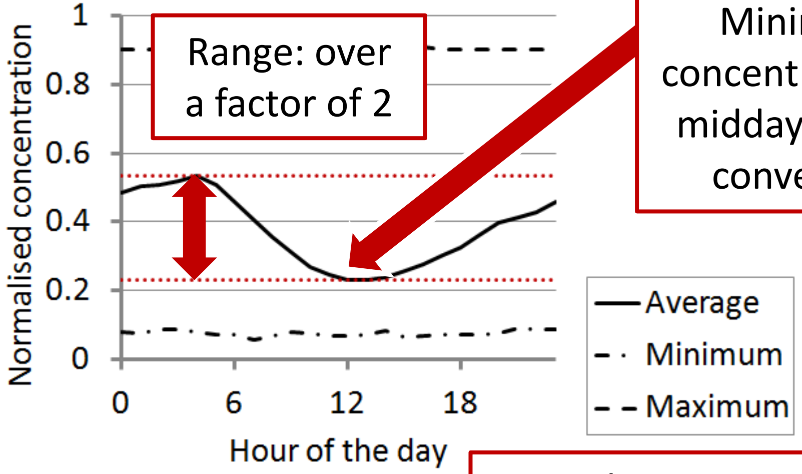
Source data – time variation

- Time-varying factors: include diurnal variation of emissions even if only annual averages (rather than exceedences) are of interest – this is because the relationship between emissions and concentrations is non-linear, due to meteorological variations

Small network of roads, single receptor
CONSTANT EMISSIONS



Real met data (one year) but with wind only from the west



Minimum concentration at midday – most convective

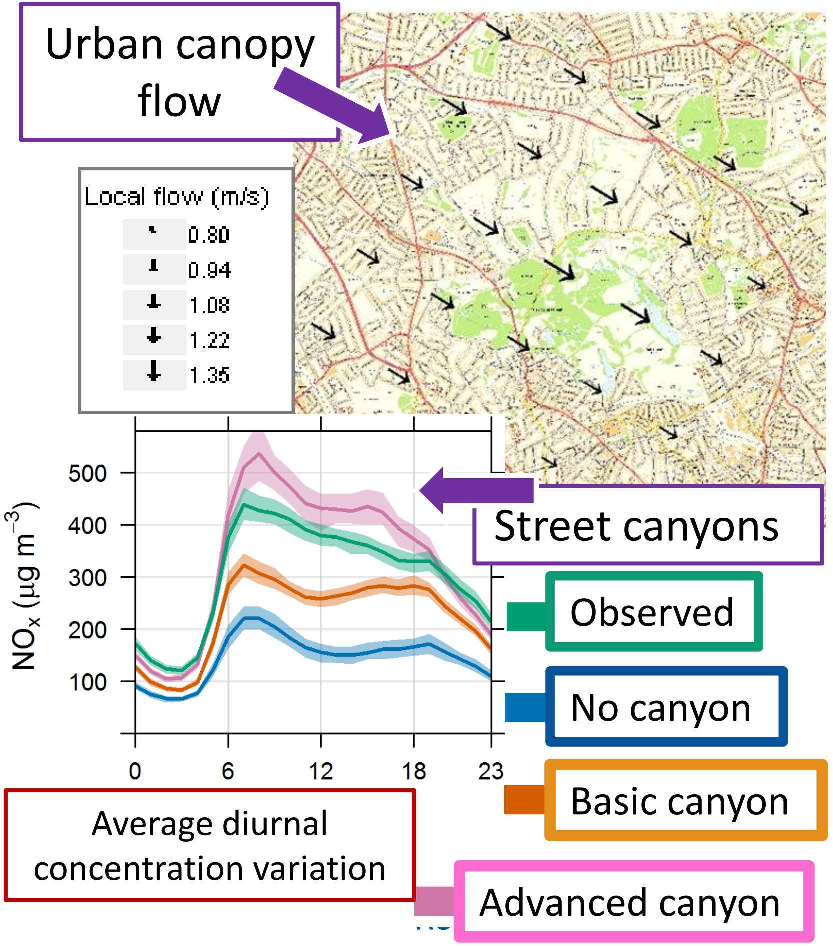
Diurnal variation of annual average concentrations

- Conclusion: **Include emissions time variation as accurately as possible!**

ADMS model configuration tips (5 of 9)

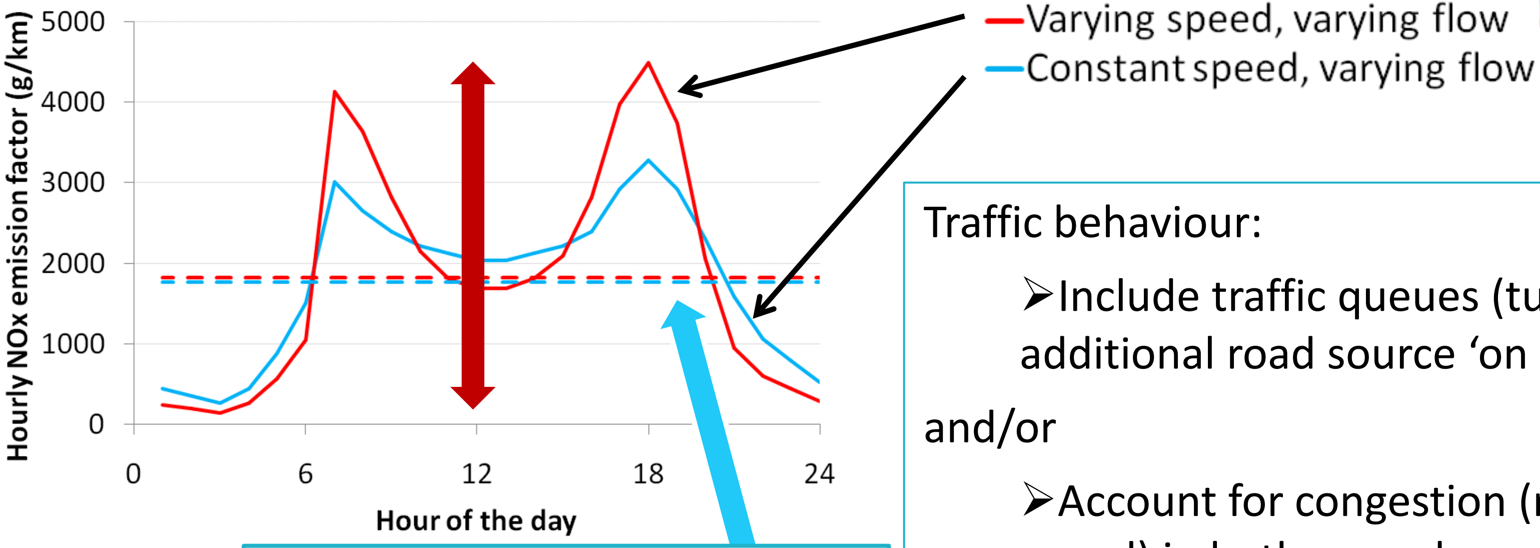
Source data – urban areas

- Ensure urban morphology is accounted for:
  - ➢ Different surface roughness at met and dispersion site (as described previously)
  - ➢ If the variation in building density and height is significant over model domain, use **Urban Canopy flow** option, which generates a spatially varying flow field (~ 1 km resolution)
  - ➢ Model **Street Canyons** if there are many buildings adjacent to the road sources. Lack of dispersion means pollution intensifies (low wind speeds, recirculation, channelling etc.)



ADMS model configuration tips (6 of 9)

Source data – urban areas



Adjustment for speed may not change the average emission significantly, but does change the peaks, so will affect concentrations

Traffic behaviour:

- Include traffic queues (turn an additional road source 'on and off')

and/or

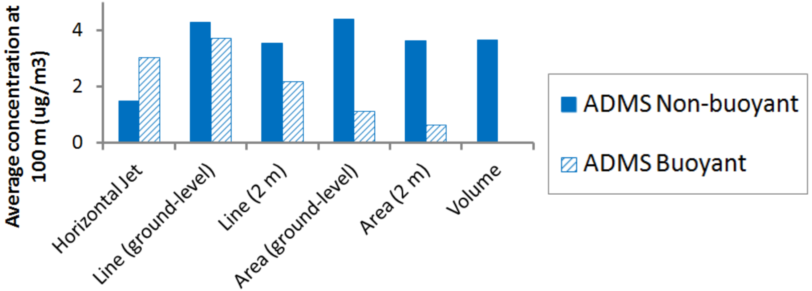
- Account for congestion (model with low speed) in both annual average and time-varying emissions (Defra's Emissions Factors Toolkit , EFT, useful)

CERC

ADMS model configuration tips (7 of 9)

Source data - industry

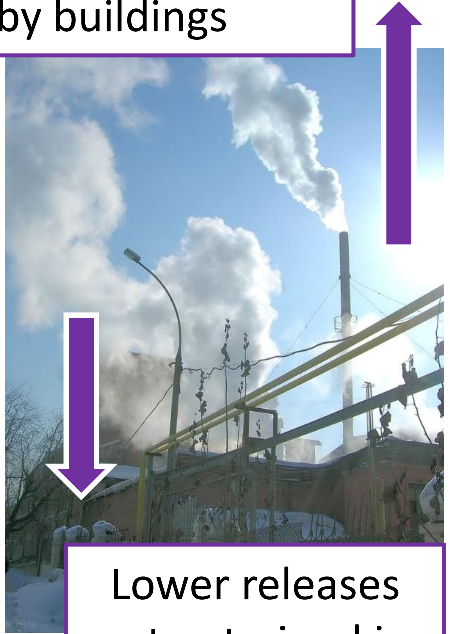
- Make sure that buildings are included in a model run that includes significant industrial sources close to buildings
- Efflux parameters (exit temperature, velocity) for high emitting industrial sources (point, area, line) should be included because significant initial buoyancy and momentum can influence dispersion beyond the site boundary



Example concentrations beyond the site boundary for an agricultural source

- If buildings and/or efflux parameters are important but data are not available, consider using a volume source to represent initial dispersion (e.g. for intensive agriculture sites)

Tall stack, buoyant releases not affected by buildings



Lower releases get entrained in building wakes

CERC

ADMS model configuration tips (8 of 9)

Source data - industry

- If stacks or flues are close together (same height and **strictly** within 3 stack diameters of shortest stack) use the combine flues option, because:
  - Plumes will act as a single source with combined source characteristics
  - Overall plume buoyancy and entrainment may be calculated more accurately
  - **Expected result:** plumes combine which results in less entrainment and therefore increased plume rise, i.e. lower concentrations at ground
  - Predicted concentrations may not be conservative *but should be more accurate*

Photos from jamesengineering.co.uk

ADMS model configuration tips (9 of 9)

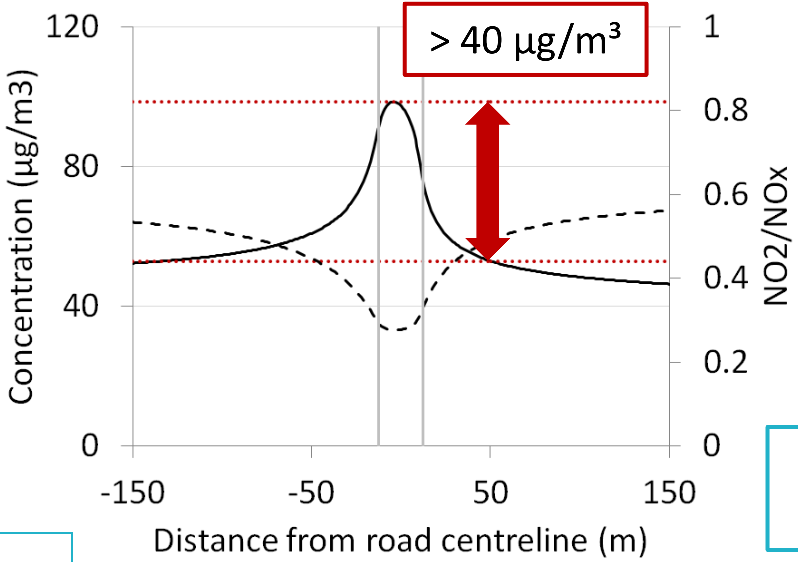
Monitor locations

• For model verification, ensure that the receptor is located correctly in terms of distance to the road carriageway edge and, if modelling street canyons, to the canyon edge

Variation:

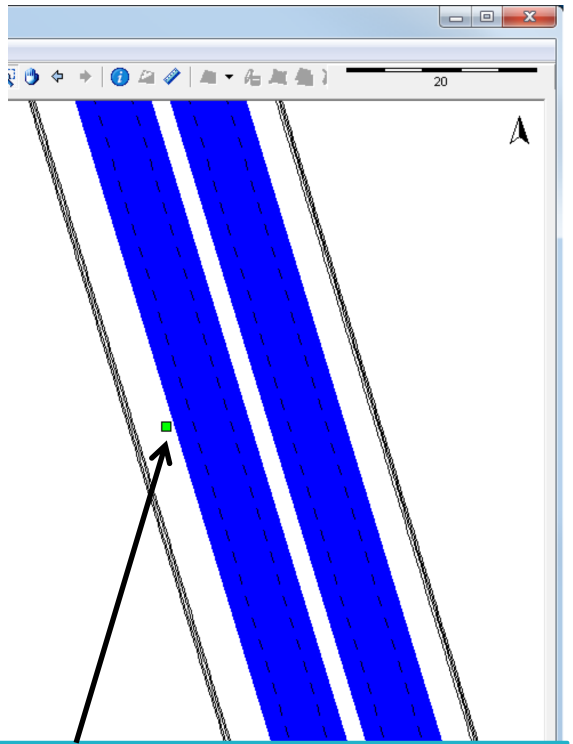
➢ Over 40 µg/m³ NO_2 within 50 m of road centreline

➢ Variation due to dispersion and chemistry



Heavily trafficked road, no canyon

Road width 25 m



Best practice: Use GIS tools to visualise monitor locations

CERC

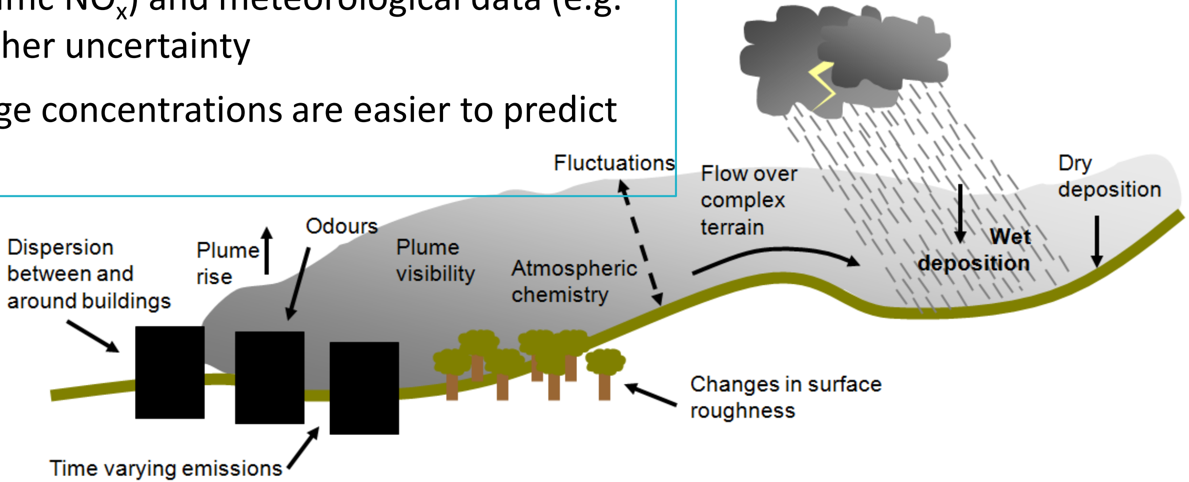
Air quality modelling tips

Model verification and model adjustment values

- **Best practice**:
  - Do as much as the practicalities and data allows
  - ADMS has been shown to demonstrate good performance in terms of air quality concentration predictions given sufficiently accurate emissions, meteorological and other data inputs. For the majority of model configurations **CERC recommend avoiding the use of post-modelling adjustment factors**
  - If a particular model configuration significantly under / over predicts, then the model inputs and settings should be reviewed (as discussed previously)
  - Comparisons against reference monitor data should be given more weighting than comparisons against diffusion tube data and sensor data
  - If standard EFT factors are being used without adjustment to account for real-world emissions of NO_x, post-modelling adjustment factors may be required; if used, follow Defra TG(16) guidance

Uncertainty of model results (1 of 3)

- Users and regulators often request a quantification of model uncertainty
- Uncertainty of model predictions relates to the model configuration:
    - ➢ Simple model configurations with well-defined emissions and meteorological data have low uncertainty (e.g. field campaigns)
    - ➢ Complex configurations (e.g. buildings, complex terrain) with uncertainty in emissions (e.g. traffic NO_x) and meteorological data (e.g. far from study location) have higher uncertainty
    - ➢ Output statistic (annual average concentrations are easier to predict than percentiles)



CERC

Uncertainty of model results (2 of 3)

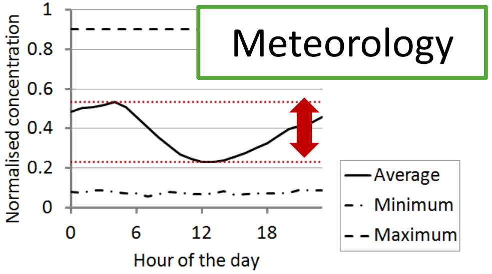
- Can consider each aspect of the model configuration separately in terms of:
  - Uncertainty level
  - Impact of a poor estimate

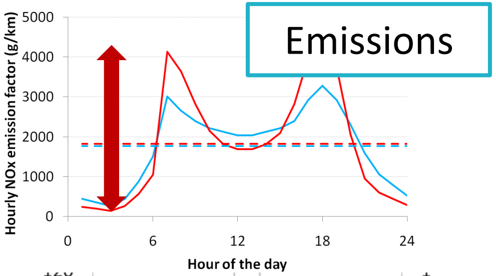
Classification	Estimated possible range for the impact of using an erroneous parameter on the magnitude of modelled concentrations
Low	< 30%
Medium	30 – 100 %
High	> 100 %

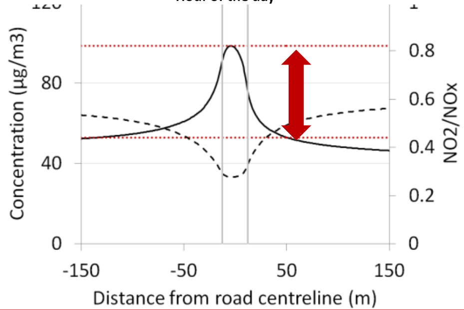
Item	Example URBAN categories	URBAN Level	URBAN Impact	URBAN Rating
Emissions	NO_x, fNO_2, PM	Low-Medium	Near linear	Low – Medium
Measurements (reference)	NO_x, NO_2, PM	Low-Medium	Near linear	Low (NO_x) – Medium (PM)
Meteorology	Wind (speed, direction), cloud cover	Low-Medium	Parameter & source dependent	Low – Medium
Source def^n	Dimensions, exit parameters	Low-Medium	Parameter & source dependent	Low – Medium
General	Street canyons, buildings, terrain	Low-Medium	Category dependent	Low – High
Model limitations	Individual buildings not modelled with road sources	Low	Category dependent	Low

Uncertainty of model results (3 of 3)

- Users & regulators often request a quantification of model uncertainty
- Uncertainty of model predictions relates to the model configuration:
    - ➢ Simple model configurations with well-defined emissions and meteorological data have low uncertainty (e.g. field campaigns)
    - ➢ Complex configurations (e.g. buildings, complex terrain) with uncertainty in emissions (e.g. traffic NO_x) and meteorological data (e.g. far from study site) have higher uncertainty
    - ➢ Output statistic (annual average concentrations are easier to predict than percentiles)
- **Best practice**:
    - ➢ Set up the model with the best emissions, meteorology, source locations and monitor locations
    - ➢ Perform sensitivity testing to quantify uncertainty e.g. minimum and maximum emissions estimates, with and without a building







Monitor locations & chemistry

CERC

Software support

- CERC provide software support…
- …so if you have trouble understanding what the model is predicting:
  - ✓ Check your model set up (see points raised in this presentation), refer to the ADMS User Guides and, for more detailed information, the Technical Specifications

    www.cerc.co.uk/UserGuides www.cerc.co.uk/TechSpecs
  - ✓If you still don’t understand what is going on, contact the Helpdesk (phone, email), who will!
  - ✓ Also, please ask us if you are trying to model a non-standard scenario and we should be able to suggest what ADMS model configuration is most suitable, or appropriate sensitivity testing

Useful references

- Best Practice approach to AQ Impact Assessments:

  Towards common standards for Air Quality Impact Assessments, Stephen Inch, GLA, ADMS-Urban & Roads User Group Meeting presentation (2016) – available from the CERC User Area

- Defra Guidance LAQM.TG(16)

  https://laqm.defra.gov.uk/documents/LAQM-TG16-February-18-v1.pdf

- IAQM Guidance:

  Moorcroft and Barrowcliffe. et al. (2017) **Land-use Planning & Development Control: Planning for Air Quality**. v1.2. Institute of Air Quality Management, London.)

- ADMS validation web page:

  www.cerc.co.uk/Validation

- Recent publication demonstrating good agreement between ADMS-Urban and reference monitors, where 'real-driving' emissions have been used:

  Hood, C., MacKenzie, I., Stocker, J., Johnson, K., Carruthers, D., Vieno, M., and Doherty, R.: **Air quality simulations for London using a coupled regional-to-local modelling system**, Atmos. Chem. Phys., 18, 11221-11245.

Any questions?

Jenny Stocker
jenny@cerc.co.uk